

# LANDSCAPE METRICS CALCULATION TO OPTIMIZE THE AESTHETICS OF FUTURE AGROFORESTRY SYSTEMS AND ITS APPLICATION WITHIN A DECISION SUPPORT TOOL

Hübner R (1\*), Busch G (2), Augenstein I (1)

\* Correspondence author: [rico.huebner@tum.de](mailto:rico.huebner@tum.de)

(1) Chair for Strategic Landscape Planning and Management, Technical University of Munich, Freising, Germany (2) Bureau for Applied Landscape Ecology and Scenario Analysis – BALSA, Göttingen, Germany

## Introduction

Protecting the scenic qualities of the landscape is a distinct objective established by the Federal Act for Nature Conservation in Germany. Moreover, potential visual impacts are a major concern in the public debate when it comes to the establishment of new land use systems. Depending on the landscape context, modern agroforestry systems (AFS) might be perceived as aesthetic enrichment or as visual intrusion (Reeg and Brix, 2008). Careful allocation and design of AFS are key issues for public acceptance. The question arises whether it is possible to avoid landscape aesthetics-related conflicts by taking possible changes to the landscape into account beforehand. The idea was to develop and apply a method of estimating and evaluating the visual effects of agroforestry using landscape metrics. This information contributes to a decision support system that also incorporates other criteria. The concept was developed and tested exemplarily in south-east Brandenburg within the research project 'Innovation Group AUFWERTEN'.

## Material and Methods

In landscape ecological research, the calculation and interpretation of landscape metrics is a frequently applied approach to analyse landscape composition and configuration using geographic information systems (GIS). More recently, GIS-based approaches have been suggested to assess the visual aesthetic quality of landscapes (Augenstein, 2002; Roser, 2011). The linkage between landscape metrics and landscape aesthetic parameters in particular is described by Palmer (2004), Uuemaa et al. (2009) and Frank et al. (2012).

### *Which indicators to choose?*

For the study, two criteria have been chosen to identify suitable areas for the siting of AFS. The criterion 'enclosure' accounts for the hypothesis that humans prefer landscapes whose constituting natural elements structure the space in such a way that new prospects might be discovered when moving deeper into the scene (Augenstein, 2002). Since the study region lacks substantial relief changes, enclosure is created by the spatial arrangement of land cover elements. It can be assumed that in landscapes richly endowed by natural vertical structures, negative impact on the landscape can be expected due to a perceived overload by additional elements. The same is expected for landscapes of intriguing visual richness due to a high diversity of (semi) natural land cover types and scenic features such as prominent single trees. This aspect is taken into account by the second criterion 'visual diversity'.

Three discrete categories of suitability were defined: category 'A' suitable areas, 'B' suitable areas with design requirements and 'C' exclusion areas. In exclusion areas, an establishment of AFS is expected to be experienced as a deterioration of scenic quality and therefore rejected.

### *How to calculate?*

Enclosure of landscape was analysed by the Line Density tool, for which all linear landscape structures are extracted from the Brandenburg habitat type mapping (Landesumweltamt Brandenburg, 2007). For the moving window analysis, a cell size of 25 x 25 m was chosen. Only landscape elements with a clear vertical structure (e.g. forest border) or a minimum of 10% coverage were considered. Obtained values are transformed to distribute between 0 and 100 and reclassified to 10 classes (**Figure 1**). For validation, a transect across all classes found in the study area was built along which panoramic images were taken using HD-videotaping.

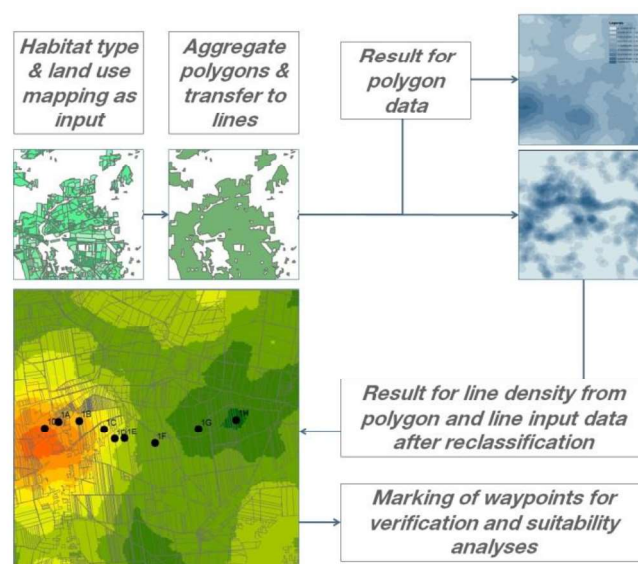


Figure 1: Procedure to determine the index for 'enclosure' and transect located waypoints for field assessment

In order to calculate the second index 'visual diversity' we modelled Shannon's Diversity Index (SHDI) which is based on the weighted geometric mean of the proportional abundances of landscape features. Its range extends from 0 to infinity, the higher the value, the more diverse the landscape (**Figure 2**). To analyse the structure of the landscape one has to leave the scale of the single landscape element and move to a higher level of observation. A fishnet with a cell size of 2.5 hectares was found to suit the study area best in order to spread obtained diversity values widely. For 21 units covering the probability distribution of diversity values, GPS waypoints were created with the software package R for each centroid and visited on several occasions during summer 2015.

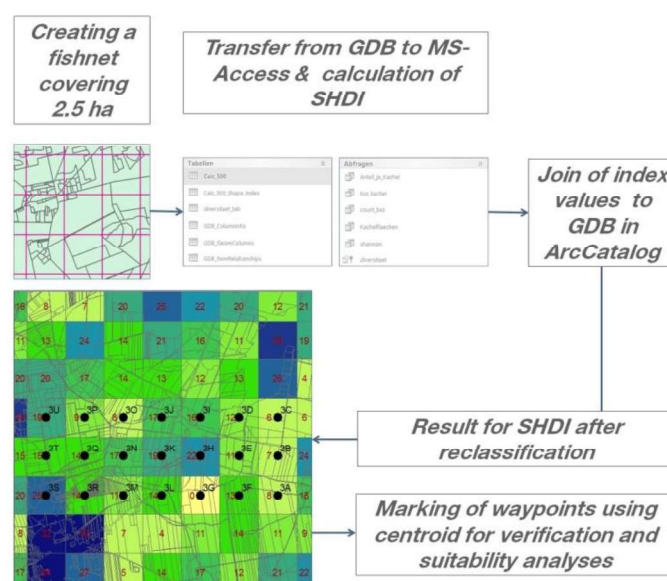


Figure 2: Procedure to determine the index for 'visual diversity' and grid located waypoints for field assessment

#### What do the experts say?

360° panoramic images representative for 9 classes of the 'enclosure' criteria and 16 panoramic images taken at the centroids within calculated 'visual diversity' classes were printed on A0-photo paper and pinned to presentation boards. To create a feeling of perspective and range, the panoramas were backed up by high-resolution aerial photographs. In a first round, four designated experts in landscape aesthetics from the field of rural landscape planning (selected according to experience and availability) judged independently the suitability of presented landscapes for the establishment of AFS. By majority voting it was decided upon the threshold values for the indices separating the map categories. However, for some landscape images, inhomogeneous voting occurred. The differences in opinion were discussed among the expert until consensus was reached.

### How to create a decision support tool?

Major goal of this tool is to support regional stakeholders and planners to identify suitable locations for the establishment of AFS located on arable land with respect to a variety of criteria, such as soil and water conservation, nature protection, crop productivity and last but not least, landscape aesthetics. Therefore the plot-specific metadata concerning 'enclosure' and 'visual diversity' were further processed within the tool.

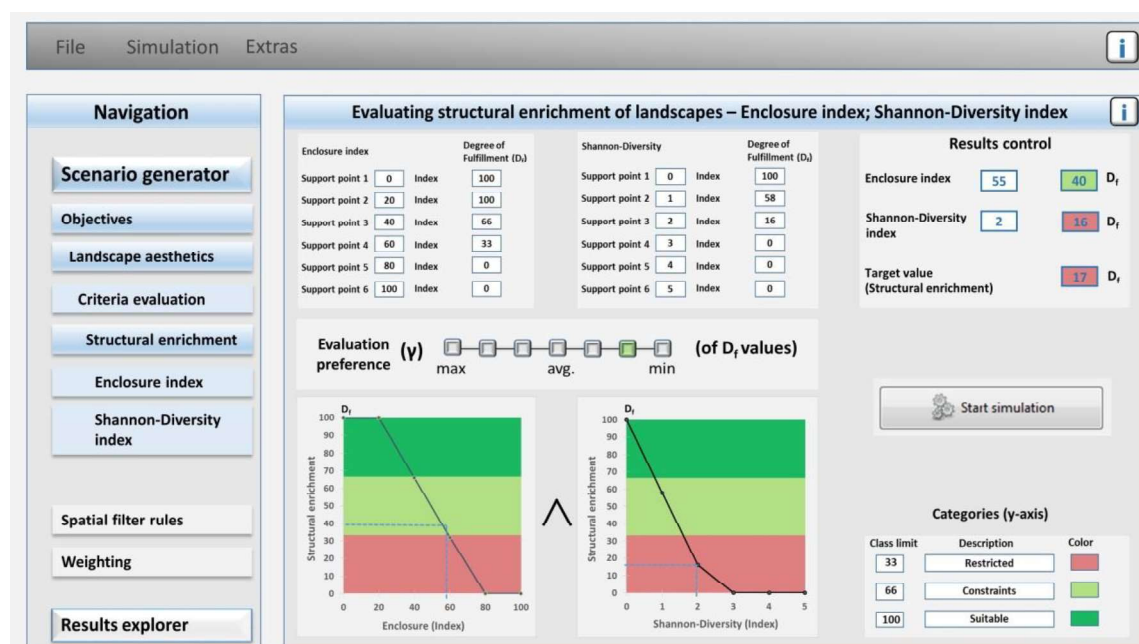


Figure 3: Procedure to evaluate the quantitative indicators 'enclosure' and 'visual diversity' within the decision support tool

**Figure 3** depicts the evaluation procedure implemented as part of a decision support tool which is currently under development within the AUFWERTEN project. Considering the results from expert rating and field assessment, an indicator-specific relation, expressed as 'Degree of fulfilment' (' $D_f$ ') could be provided. In a second step, a joint evaluation was generated by combining the indicator-specific ' $D_f$ '-values. The procedure applied followed an approach by Malczewski and Rinner (2005) and allows the user to qualitatively express his/her evaluation preference by choosing between seven options. This way the combined evaluation ranges between a sole minimum to maximum selection allowing for intermediate steps. Each selection corresponds to a predefined weight pair that is assigned to the ' $D_f$ ' ordered-value pair accordingly (Malczewski and Rinner, 2005).

Table 5: Example of the ordered weight average calculation procedure

Indicator	$D_f$ value	$y$ order weight	$\frac{D_f * y}{2}$	$\sum_{j=0}^{100} (D_f)$
'enclosure'	40	0.21	8.4	21.04
'visual diversity'	16	0.79	12.64	

$D_f$ -value >66.6 results in a recommendation for AFS (cat. A), <33.3 results in restrictions with respect to the establishment of AFS (cat. C), for in-between values, certain constraints e.g. with respect to design and siting are mandatory (cat. B).

An example for the calculation for a specific plot of land is presented in Table 1. The resulting evaluation value 21.04 means with respect to the underlying classification that this particular site is not suitable for AFS allocation from a landscape aesthetics perspective.

### Results

Further GIS calculation using a weighted mean approach allowed attributing the area extensive values to the individual field plots in the study area, so further processing based on the filed ID was made possible. Connecting the indices with the suitability categories 'A', 'B' and 'C' allowed generating area-specific suitability maps for the ideal siting of AFS. A first application of this evaluation procedure in the case study region of AUFWERTEN, revealed that if the criterion 'enclosure' was solely applied, almost 70% of the available sites would fully suit the establishment AFS in cat. 'A'. Another 25% of the plots would also be suitable, but under design

obligations. Only a fraction of the land determined by the 'enclosure'-criterion would be unsuitable (approx. 5% of available sites) (Table 2).

Table 6: Results of a first suitability assessment of arable sites in study region from a landscape aesthetics perspective

<i>Suitability due to 'enclosure'</i>	<i>% of agricultural sites</i>	<i>Suitability due to 'visual diversity'</i>	<i>% of agricultural sites</i>	<i>Suitability due to indicator combination</i>	<i>% of agricultural sites</i>
A	70	A	7	A	11
B	25	B	31	B	38
C	5	C	62	C	51

When the 'visual diversity' criteria would be applied separately, the outcome is far less promising for AFS. More than half of the agricultural land in the study area would fall under category 'C' thus are unsuitable for the installation of AFS. Only 7% of the plots are entirely suitable in cat. 'A'. However, for 31% of the plots, design measures could still enable the establishment of AFS (Table 2).

Combining the two indices within the decision support tool, a total of 11% sites are especially benefiting from the establishment of AFS. For 38% of the sites design requirements would still generate area available. However about half of the agricultural sites are – under landscape aesthetics restrictions – not benefiting from new AFS and thus these areas should be avoided (Table 2).

### Discussion and Outlook

A first application of this evaluation procedure in the case study region in south-east Brandenburg, Germany, revealed that the site suitability is indicator-specific and varies considerably between the criteria 'enclosure' and 'visual diversity'.

The major restrictions in terms of AFS allocation originate from the 'visual diversity' evaluation determined by the SHDI. Despite the current, minimum-oriented selection of 'D<sub>i</sub>' values, very high suitability due to positive evaluation of the 'enclosure' indicator can compensate the SHDI restrictions to a small extent. As a result, there is a small increase of suitable sites in cat. 'A' and 'B' compared to the sole 'visual diversity'-restrictions. Approximately 51% of the agricultural sites fall under cat. 'C' thus the aesthetic requirements alone bring strong restrictions to the establishment of new AFS in the study region.

These preliminary results will thus be discussed further, especially, since it is planned to add more features to the decision support tool in the near future, all representing different ecosystem services. Although AFS are a promising form of future land use, with multiple benefits going far beyond improvements of landscape aesthetics, however, in order to prevent a negative societal discourse as experienced with other biomass projects in Germany, the aesthetics is a valid argument. Visual landscape quality is an important aspect for the local population. The tool proposed in this study will be used in participatory processes and help to take public concerns into account.

### References:

- Augenstein I. (2002) Die Ästhetik der Landschaft – Ein Bewertungsverfahren für die planerische Umweltvorsorge. Weißensee Verl., Berlin, 170, VII S. pp.
- Frank S, Fürst C, Koschke L, Makeschin F. (2012) A contribution towards a transfer of the ecosystem service concept to landscape planning using landscape metrics. *Ecological Indicators* 21: 30-38.
- Landesumweltamt Brandenburg (ed). (2007) Biotopkartierung Brandenburg – Band 2 Beschreibung der Biotoptypen. Potsdam, 512 pp.
- Malczewski J, Rinner C. (2005) Exploring multicriteria decision strategies in GIS with linguistic quantifiers: A case study of residential quality evaluation. *Journal of Geographical Systems* 7: 249-268.
- Palmer JF. (2004) Using spatial metrics to predict scenic perception in a changing landscape: Dennis, Massachusetts. *Landscape and Urban Planning* 69: 201-218.
- Reeg T, Brix M. (2008) Zielgebietsauswahl für Agroforstsysteme – Vorschläge unter Berücksichtigung der verschiedenen Interessen in der Landnutzung. *Naturschutz und Landschaftsplanung* 40: 173.
- Roser F. (2011) Entwicklung einer Methode zur großflächigen rechnergestützten Analyse des landschaftsästhetischen Potenzials. Weißensee Verl., Berlin, 197 pp.
- Uuemaa E, Antrop M, Roosaare J, Marja R, Mander Ü. (2009) Landscape Metrics and Indices: An Overview of Their Use in Landscape Research. *Living Reviews in Landscape Research* 3: 1-28.